located on a mountain and has excellent line-of-sight conditions to most of the roof tops. Therefore, many of the installations utilized very short mounting structures for the receive antennas. The average height above ground for receive antenna installations was under 20' AGL. Therefore, several of the installations gave insufficient height to allow the return path transmitters unobstructed electrical path to Tucson House.

Return Path Installations

In order to verify the prediction methodology, the 96 theoretical grid points defined in the methodology were utilized as a guide for determining the desired location of the installations. The grid point locations were overlaid on a map of existing People's Choice TV subscribers. Subscribers located in the vicinity of a grid point were contacted and invited to participate in the test. Sites were selected as close as possible to the location of the grid points. Figure 4.5 shows the final location of the actual installations.

Not all 96 locations could be installed. The southeast quadrant of the cell contains a small mountain and sparse subscribers. Three return path transmitters could not be installed at grid points in this quadrant. Several transmitters were installed behind the mountain, even though the path to Tucson House was obstructed. This allowed the verification of terrain shielding as an acceptable means of interference protection. However, a total of 93 transmit sites were installed.

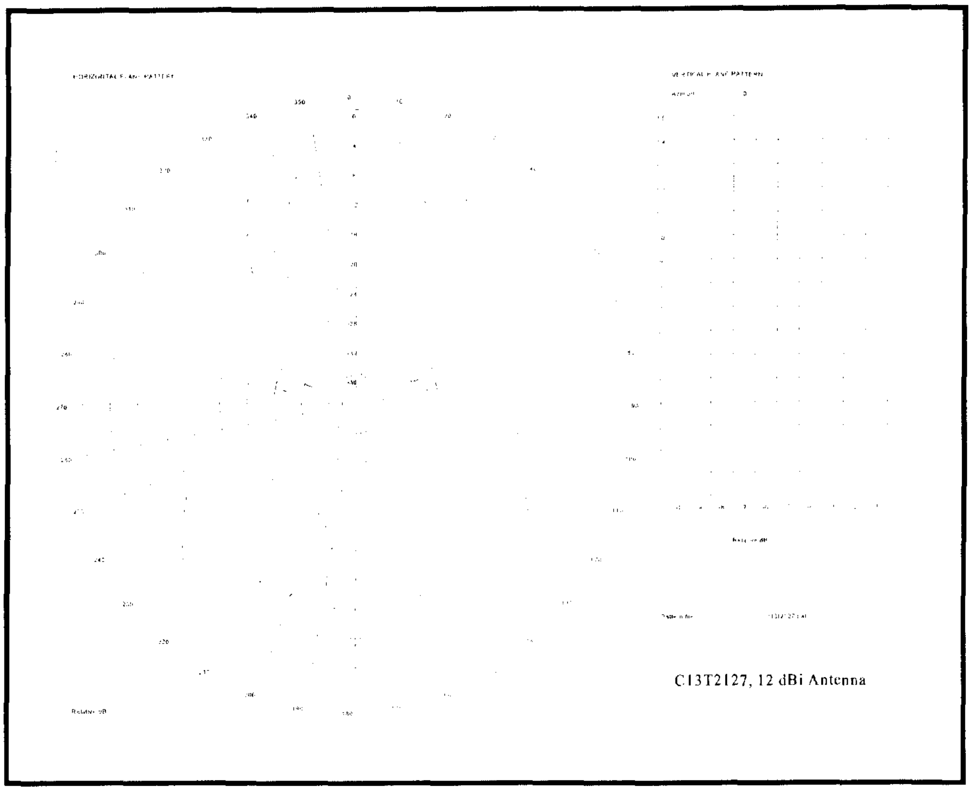
The return path transmitters were mounted to existing antenna mounts on subscriber's roofs as described previously. In cases where insufficient height was available to achieve a totally unobstructed path to Tucson House, small extensions or possible new mounting locations on the roof top were tried. If the desired amount of received signal level could not be achieved at the hub, the return path transmitter was allowed to run at maximum EIRP for the test. In cases where the received signal level at the hub center was in excess of the desired level, attenuators were added to reduce the EIRP.

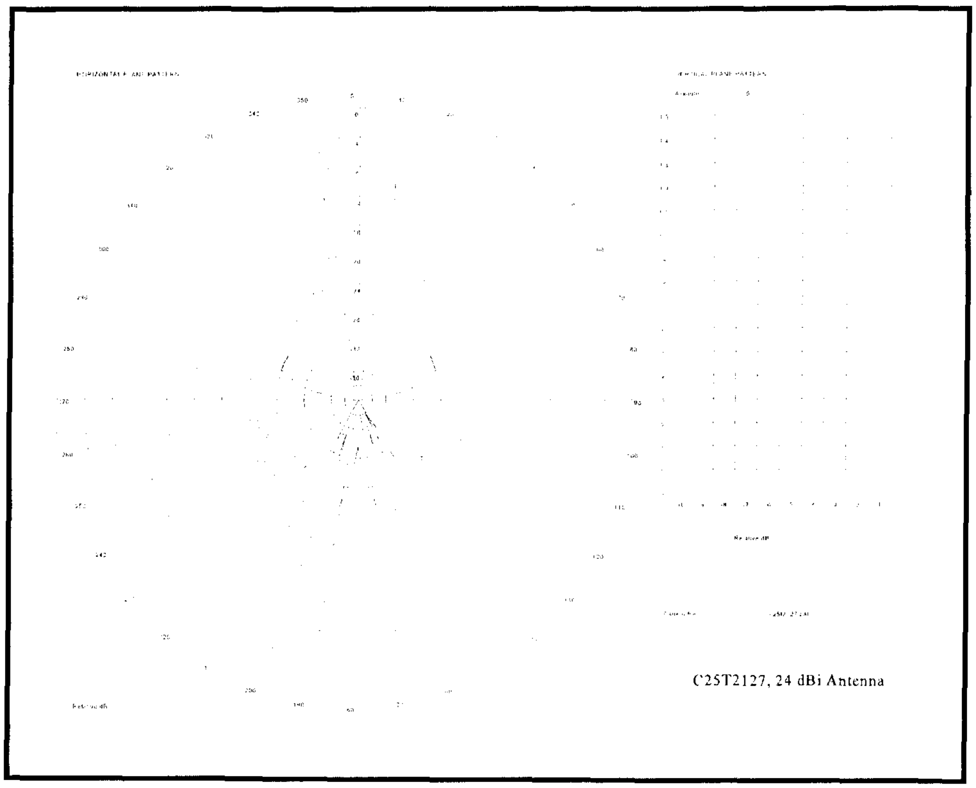
Each transmission system consisted of a crystal oscillator, transmitter and antenna. The crystal oscillator provided an RF output in the range of 118 to 122 MHz to the transmitter. The transmitter converted this frequency to microwave in the 2156 to 2160 MHz region. The signal was then broadcast through a directional antenna to the hub center.

Hub Installation

A receive system consisting of an omnidirectional antenna, a bandpass filter and a wideband amplifier were installed on the roof top of Tucson House and utilized to receive signals from each of the return path transmitters. The output of the amplifier was connected to a spectrum analyzer for monitoring. Figure 4.6 is a block diagram of the receive equipment installation at Tucson House.

In an actual two-way system design, the return path transmitter output power will be adjusted to give a desired received signal level at the hub center. For the test in Tucson, a desired receive signal level at the input to the spectrum analyzer of -55 dBm was selected. This seemed to be a level achievable by a significant number of return path sites when utilizing the low gain transmit antenna. Return path systems were adjusted to give as close to -55 dBm at the hub as possible. Also, when the transmit antennas were changed from the 12 to 24 dBi models, the levels were then readjusted to give -55 dBm at the hub.





<u>FIGURE 4.1 - RETURN PATH TRANSMIT ANTENNA PATTERNS</u>

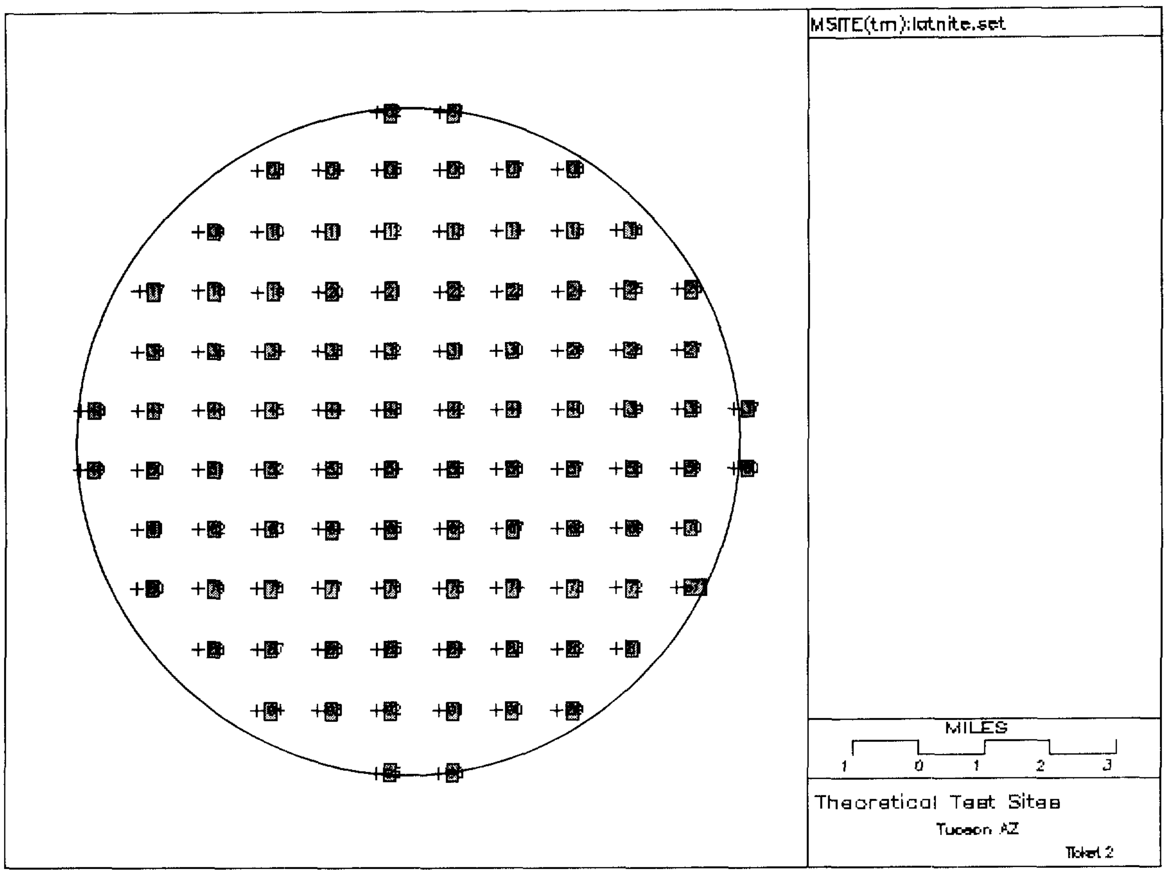
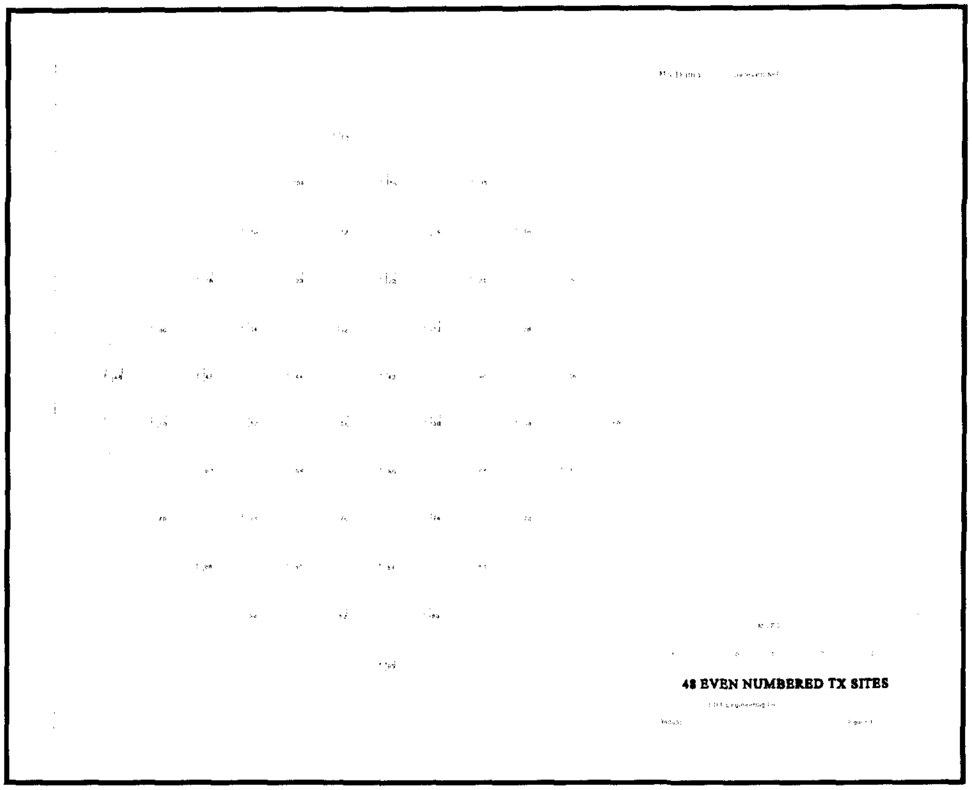
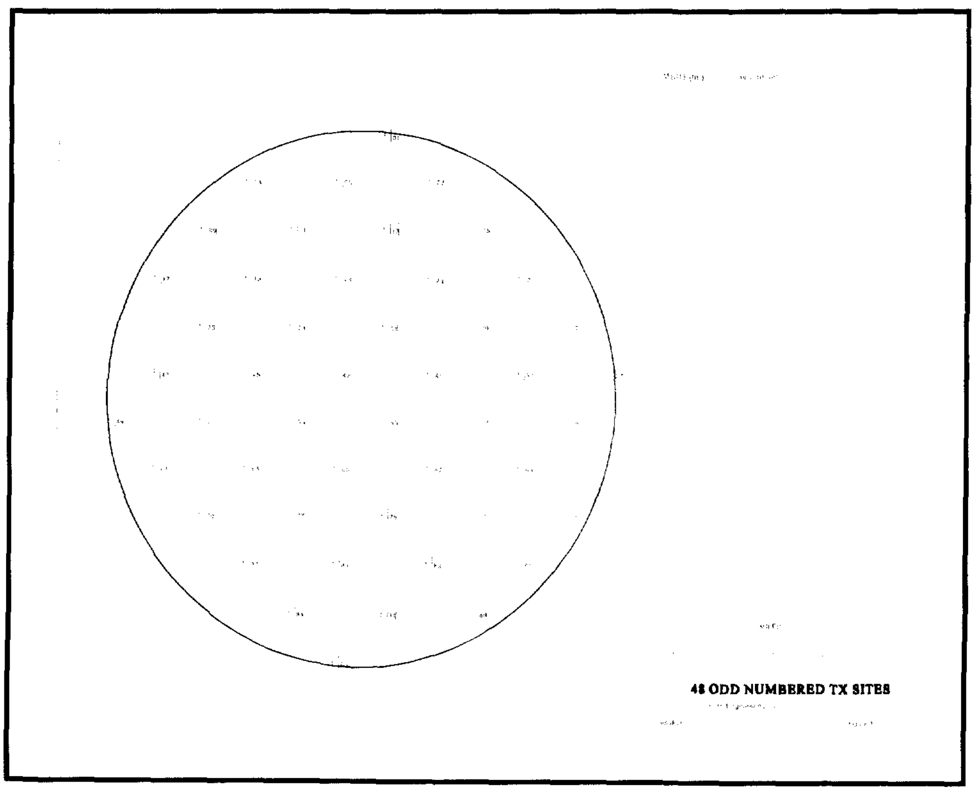


FIGURE 4.2 - THEORETICAL GRID POINT LOCATIONS IN 5 MILE CELL.





<u>**FIGURE 4.3 - EVEN AND ODD TRANSMIT SITES**</u>

Tuscon: Theoretical no terrain High Resolution (.12 mile/box) +22dBm EIRP and +12dBi antenna. Data every 5 degrees and 5.5 miles range.															
			96 Tx on		48 Tx only (odd)		48 Tx only (even)		Delta		Delta		Delta		
Data Poi	Bearing		Value (dBm)		Value (dBm)		Value (dBm)		48 on (odd/even)		(96/48 odd)		(96/48 even)		
1	0	=	-21.21		-24.29		-24.14		-0.15		3.08		2.93		
2	5	=	-21.44		-23.20		-26.23		3.03		1.76		4.79		
3	10	=	-21.82		-23.33		-27.16		3.83		1.51		5.34		
4	15	=	-22.72		-25.19		-26.34		1.15		2.47		3.62		
5	20	=	-23.10	AVG	-24.97	AVG	-26.58	AVG	1.61	AVG	1.87	AVG	3.48	AVG	
6	25	=	-22.67	-22.78	-26.52	-25.86	-24.97	-26.05	-1.55	0.19	3.85	3.08	2.30	3.27	
7	30	=	-21.80		-26.64		-23.53		-3.11		4.84		1.73		
8	35	=	-22.40	MAX	-26.57	MAX	-24.50	MAX	-2.07	MAX	4.17	MAX	2.10	MAX	
9	40	=	-22.56	-20.20	-27.22	-22.27	-24.38	-22.29	-2.84	5.21	4.66	6.20	1.82	6.36	
10	45	=	-23.72		-28.10		-25.68		-2.42		4.38		1.96		
11	50	=	-23.24	MIN	-27.87	MIN	-26.13	MIN	-1.74	MIN	4.63	MIN	2.89	MIN	
12	55	=	-22.93	-24.61	-26.48	-28.35	-25.46	-28.93	-1.02	-5.01	3.55	1.15	2.53	1.19	
13	60	=	-23.70		-26.30		-27.15		0.85		2.60		3.45		
14	65	=	-24.61		-27.08		-28.23		1.15		2.47		3.62		
15	70	=	-23.34		-27.67		-25.33		-2.34		4.33		1.99		
16	75	=	-23.59		-26.13		-27.14		1.01		2.54		3.55		
17	80	=	-21.16		-22.40		-27.23		4.83		1.24		6.07		
18	85	=	-21.44		-23.37		-25.88		2.51		1.93		4.44		
19	90	=	-20.56		-24.73		-22.66		-2.07		4.17		2.10		
20	95	=	-22.44		-26.32		-24.72		-1.60		3.88		2.28		
21	100	=	-22.34		-27.87		-23.77		-4.10		5.53		1.43		
22	105	=	-23.87		-27.09		-26.68		-0.41		3.22		2.81		
23	110	=	-22.56		-25.26		-25.90		0.64		2.70		3.34		
24	115	=	-23.63		-25.93		-27.49		1.56		2.30		3.86		
25	120	=	-23.58		-26.71		-26.48		-0.23		3.13		2.90		
26	125	=	-23.21		-25.40		-27.22		1.82		2.19		4.01		
27	130	=	-23.32		-25.11		-28.05		2.94		1.79		4.73		
28	135	=	-22.40		-23.58		-28.67		5.09		1.18		6.27		
29	140	=	-23.49		-25.00		-28.83		3.83		1.51		5.34		
30	145	=	-23.10		-26.00		-26.22		0.22		2.90		3.12		
31	150	=	-22.83		-25.08		-26.84		1.76		2.25		4.01		
32	155	=	-23.70		-26.23		-27.25		1.02		2.53		3.55		
33	160	=	-22.71		-25.25		-26.20		0.95		2.54		3.49		
34	165	=	-23.42		-26.75		-26.13		-0.62		3.33		2.71		
35	170	=	-22.38		-27.75		-23.87		-3.88		5.37		1.49		
36	175	=	-23.11		-26.51		-25.77		-0.74		3.40		2.66		

TABLE 4.1 - COMPARISON OF SIGNAL LEVELS FOR ODD AND EVEN NUMBERED TRANSMITTERS.

Tuscon: Theoretical no terrain High Resolution (.12 mile/box) +22dBm EIRP and +12dBi antenna. Data every 5 degrees and 5.5 miles range.								
			96 Tx on	48 Tx only (odd)	48 Tx only (even)	Delta	Delta	Delta
Data Poi	Bearing		Value (dBm)	Value (dBm)	Value (dBm)	48 on (odd/even)	(96/48 odd)	(96/48 even)
37	180	=	-20.85	-24.17	-23.58	-0.59	3.32	2.73
38	185	=	-21.96	-24.00	-25.94	1.94	2.04	3.98
39	190	=	-21.18	-22.33	-27.54	5.21	1.15	6.36
40	195	=	-23.38	-26.02	-26.79	0.77	2.64	3.41
41	200	=	-23.91	-28.08	-26.01	-2.07	4.17	2.10
42	205	=	-24.52	-27.23	-27.85	0.62	2.71	3.33
43	210	=	-23.48	-26.16	-26.83	0.67	2.68	3.35
44	215	=	-23.35	-26.57	-26.16	-0.41	3.22	2.81
45	220	=	-23.80	-28.11	-25.82	-2.29	4.31	2.02
46	225	=	-23.93	-28.35	-25.88	-2.47	4.42	1.95
47	230	=	-23.16	-27.52	-25.15	-2.37	4.36	1.99
48	235	=	-22.59	-26.72	-24.71	-2.01	4.13	2.12
49	240	=	-22.22	-26.97	-23.98	-2.99	4.75	1.76
50	245	=	-23.24	-27.16	-25.51	-1.65	3.92	2.27
51	250	=	-22.46	-25.72	-25.82	0.10	3.26	3.36
52	255	=	-23.39	-26.08	-26.75	0.67	2.69	3.36
53	260	=	-22.03	-23.41	-27.70	4.29	1.38	5.67
54	265	=	-22.36	-24.63	-26.27	1.64	2.27	3.91
55	270	=	-20.20	-22.27	-24.42	2.15	2.07	4.22
56	275	=	-21.29	-25.86	-23.16	-2.70	4.57	1.87
57	280	=	-21.10	-27.30	-22.29	-5.01	6.20	1.19
58	285	=	-23.97	-27.64	-26.41	-1.23	3.67	2.44
59	290	=	-23.05	-25.80	-26.34	0.54	2.75	3.29
60	295	=	-24.06	-26.51	-27.72	1.21	2.45	3.66
61	300	=	-23.34	-26.20	-26.50	0.30	2.86	3.16
62	305	=	-22.93	-25.73	-26.68	0.95	2.80	3.75
63	310	=	-24.05	-25.75	-28.93	3.18	1.70	4.88
64	315	=	-22.85	-24.19	-28.62	4.43	1.34	5.77
65	320	=	-23.76	-25.54	-28.49	2.95	1.78	4.73
66	325	=	-21.91	-24.11	-25.91	1.80	2.20	4.00
67	330	=	-23.13	-26.40	-25.91	-0.49	3.27	2.78
68	335	=	-23.82	-26.48	-27.21	0.73	2.66	3.39
69	340	=	-22.43	-24.23	-27.13	2.90	1.80	4.70
70	345	=	-23.20	-26.76	-25.71	-1.05	3.56	2.51
71	350	=	-21.53	-26.52	-23.19	-3.33	4.99	1.66
72	355	=	-21.73	-25.47	-24.12	-1.35	3.74	2.39

TABLE 4.1 (CONTINUED)- COMPARISON OF SIGNAL LEVELS FOR ODD AND EVEN NUMBERED TRANSMITTERS.

Transverter LO:	2278.00	MHz
Microwave Start:	2156.00	MHz
Microwave End	2160.00	MHz
RF Start:	118.00	MHz
RF End:	122.00	MHz
Channel Guardband:	0.00	KHz
Channel Separation	30.00	KHz
Group Guardband	150.00	KHz

	Zone	RF (MHz)	Microwave (MHz)
Group 1	I	118.00	2160.00
	II	118.03	2159.97
	III	118.06	2159.94
	IV	118.09	2159.91
	V	118.12	2159.88
	VI	118.15	2159.85
	VII	118.18	2159.82
	VIII	118.21	2159.79
Group 2	I	118.24	2159.76
	II	118.27	2159.73
	III	118.30	2159.70
	IV	118.33	2159.67
	V	118.48	2159.52
	VI	118.51	2159.49
	VII	118.54	2159.46
	VIII	118.57	2159.43
Group 3	I	118.60	2159.40
	II	118.63	2159.37
	III	118.66	2159.34
	IV	118.69	2159.31
	V	118.72	2159.28
	VI	118.75	2159.25
	VII	118.78	2159.22
	VIII	118.81	2159.19
Group 4	I	118.96	2159.04
	II	118.99	2159.01
	III	119.02	2158.98
	IV	119.05	2158.95
	V	119.08	2158.92
	VI	119.11	2158.89
	VII	119.14	2158.86
	VIII	119.17	2158.83
Group 5	I	119.20	2158.80
	II	119.23	2158.77
	III	119.26	2158.74
	IV	119.29	2158.71
	V	119.44	2158.56
	VI	119.47	2158.53
	VII	119.50	2158.50
	VIII	119.53	2158.47
Group 6	I	119.56	2158.44
	II	119.59	2158.41
	III	119.62	2158.38
	IV	119.65	2158.35
	V	119.68	2158.32
	VI	119.71	2158.29
	VII	119.74	2158.26
	VIII	119.77	2158.23
Group 7	I	119.92	2158.08
	II	119.95	2158.05
	III	119.98	2158.02
	IV	120.01	2157.99
	V	120.04	2157.96
	VI	120.07	2157.93
	VII	120.10	2157.90
	VIII	120.13	2157.87

	Channel	RF (MHz)	Microwave (MHz)
Group 8	I	120.16	2157.84
	II	120.19	2157.81
	III	120.22	2157.78
	IV	120.25	2157.75
	V	120.40	2157.60
	VI	120.43	2157.57
	VII	120.46	2157.54
	VIII	120.49	2157.51
Group 9	I	120.52	2157.48
	II	120.55	2157.45
	III	120.58	2157.42
	IV	120.61	2157.39
	V	120.64	2157.36
	VI	120.67	2157.33
	VII	120.70	2157.30
	VIII	120.73	2157.27
Group 10	I	120.88	2157.12
	II	120.91	2157.09
	III	120.94	2157.06
	IV	120.97	2157.03
	V	121.00	2157.00
	VI	121.03	2156.97
	VII	121.06	2156.94
	VIII	121.09	2156.91
Group 11	I	121.12	2156.88
	II	121.15	2156.85
	III	121.18	2156.82
	IV	121.21	2156.79
	V	121.36	2156.64
	VI	121.39	2156.61
	VII	121.42	2156.58
	VIII	121.45	2156.55
Group 12	I	121.55	2156.45
	II	121.58	2156.42
	III	121.61	2156.39
	IV	121.64	2156.36
	V	121.67	2156.33
	VI	121.70	2156.30
	VII	121.73	2156.27
	VIII	121.76	2156.24
Reserve	SPARE	121.91	2156.09
	SPARE	121.94	2156.06
	SPARE	121.97	2156.03
	SPARE	122.00	2156.00

TABLE 4.2 - RETURN PATH FREQUENCY PLAN.

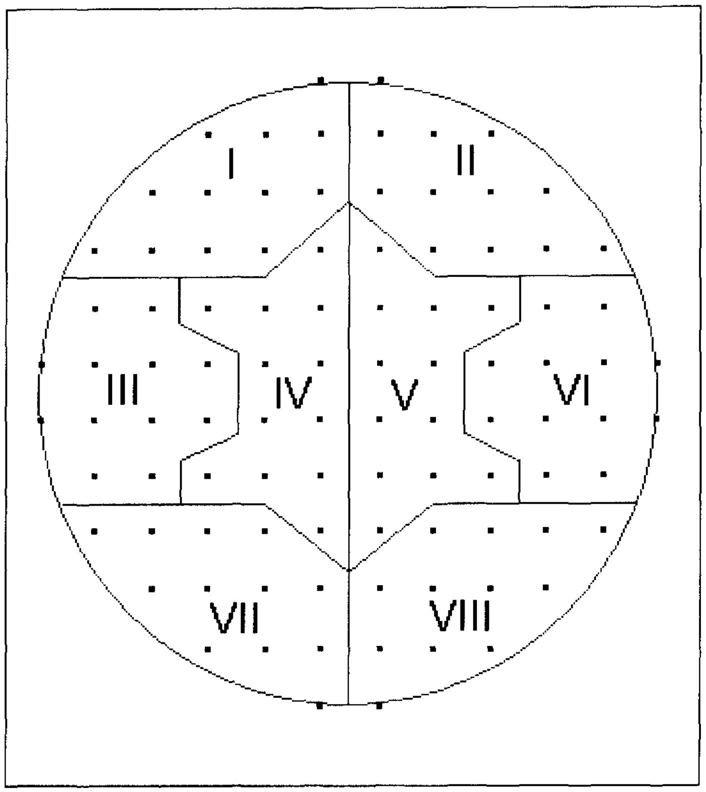


FIGURE 4.4 - RETURN PATH TRANSMITTER FREQUENCY ZONES

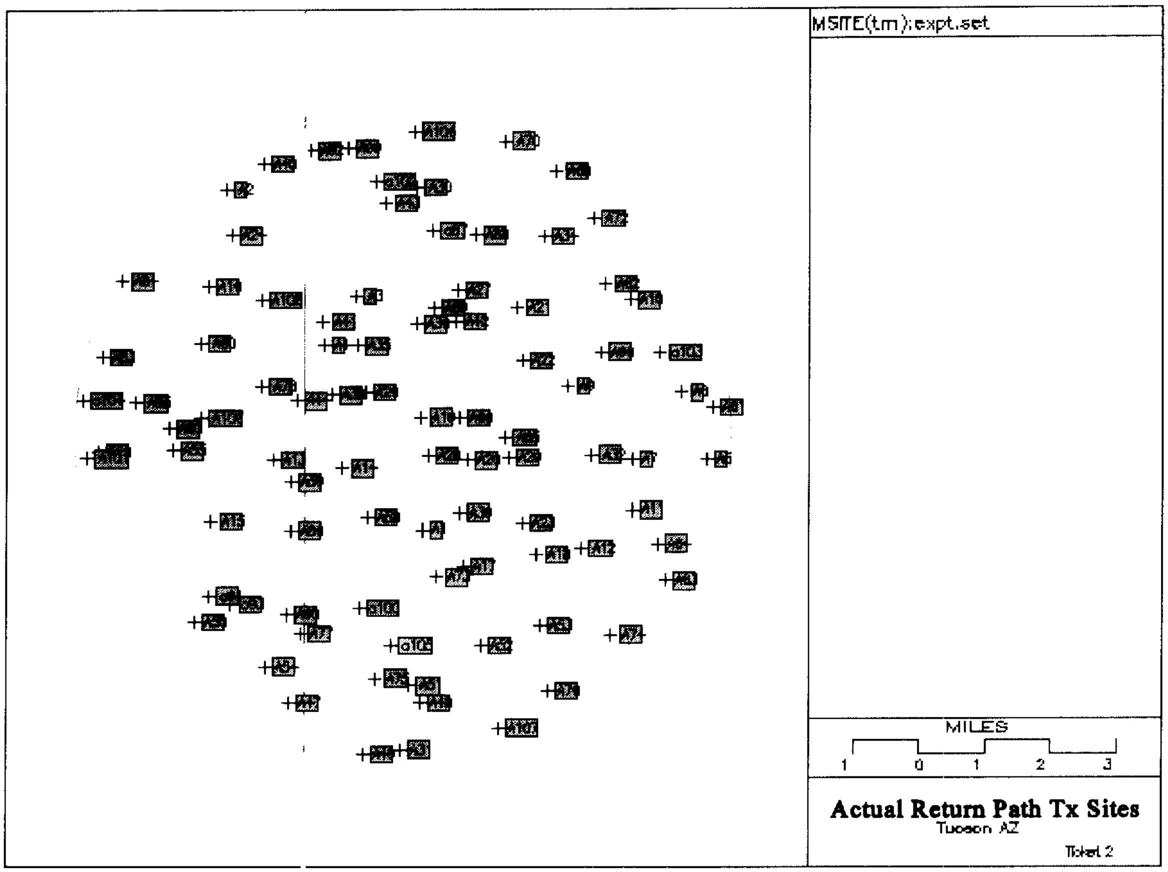


FIGURE 4.5 - ACTUAL RETURN PATH TRANSMIT SITE LOCATIONS IN TUCSON CELL.

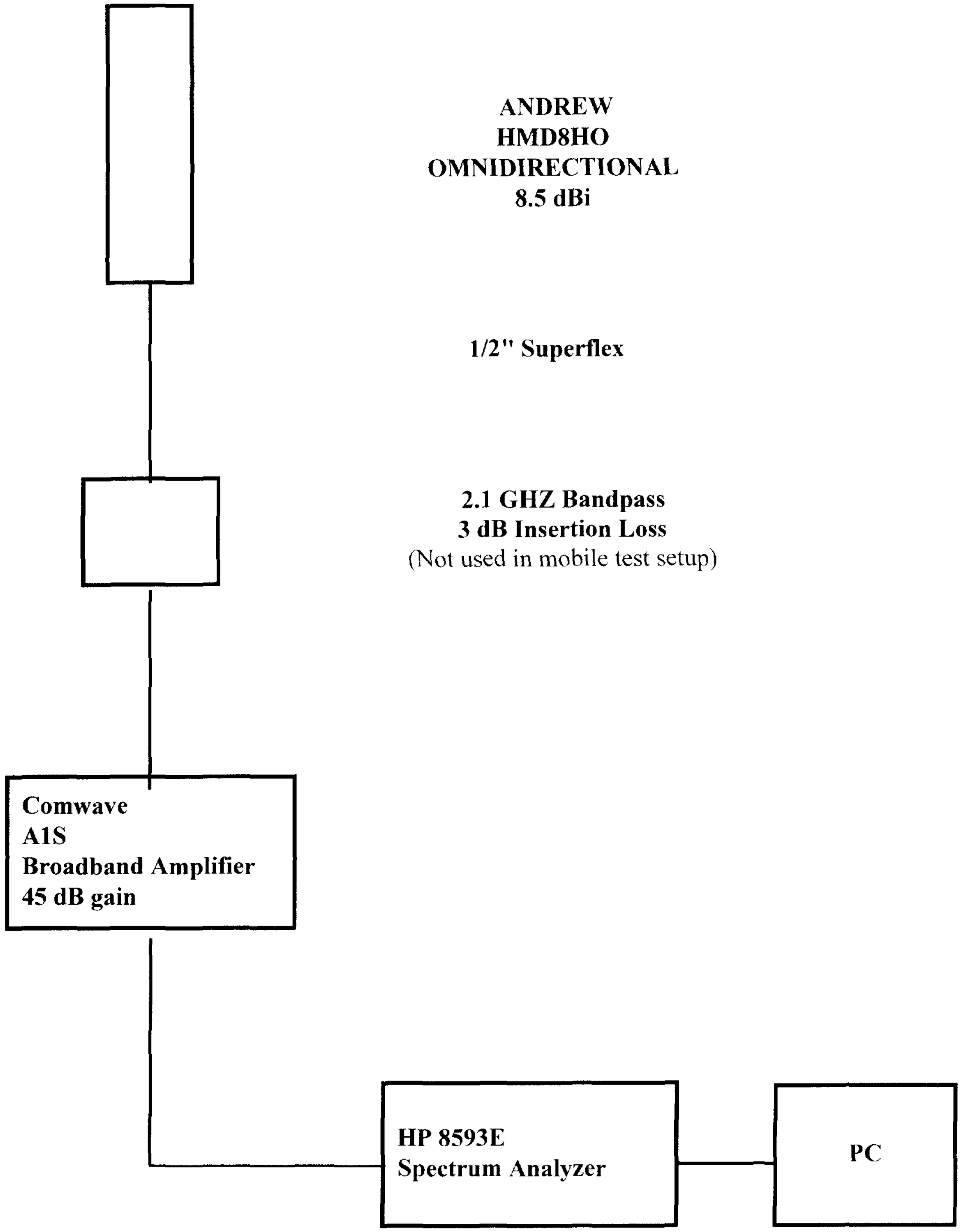


FIGURE 4.6 HUB AND TEST VAN EQUIPMENT CONFIGURATION.

4

Measurement Techniques

Equipment

A measurement system was designed to collect the received signal levels from all of the return path transmitters at points outside of the cell. The system consisted of an omnidirectional receive antenna (Andrew HMD8HO) and a low noise broadband amplifier (Comwave SB1) mounted on a telescopic tower attached to a van. The output of the amplifier was connected to a spectrum analyzer (HP8569E) located in the van via a run of Superflex Heliax cable. The total gain of the receive system is approximately 53.5dB.

The analyzer was connected to a PC computer via an HPIB connection. The computer was equipped with special HP software which allowed the capturing of the contents of the spectrum analyzer screen in both a graphics and text format. The spectrum analyzer was also controlled by the PC and allowed semi-automation of the testing process.

Test Site Selection

The location of test sites was dictated by the road system in Tucson. It was desired to have test sites located at points on concentric circles surrounding the Tucson cell and at distances of 0.5, 1.0, 2.0 and 4.0 miles from the cell boundary. Also, it was desired to have test sites spaced at 5 degree increments around the cell for the 0.5 mile circle and 10 degree increments for all other circles. Figure 5.1 is a diagram showing the desired location of test sites and the actual test sites used in Tucson.

The test sites were numbered sequentially, starting at a point due south of Tucson House and 5.5 miles out. A total of 136 test sites were utilized.

Receive Antenna Heights

The test data was collected at receive antenna heights of 30', 40' and 50' above ground level. Taking data at various heights allows the evaluation of the prediction model as terrain becomes less of a factor in path obstruction.

Correlations at Tucson House

Because the return path transmitters were installed in businesses and homes, it was extremely important to verify on a regular basis that each transmitter remained operational. Therefore, periodic trips were made to Tucson House to view the output of the receive system and verify that all of the transmitters remained operational. If a transmitter was off, the subscriber was contacted immediately or a service technician was dispatched immediately to remedy the situation. Initially, tests were conducted at Tucson House three times a day. As the system settled, testing was reduced to twice daily.

Measurements

Measurements were made at every test site of the individual power contributed by each return path transmit site and of the total power. The individual power levels were measured by programming the spectrum analyzer to select 0.5 MHz blocks of the MDS2-A channel and capturing the data on the PC. Eight sets of data consisting of 8 bit map files and 8 text files were captured for each receive antenna height (30', 40', 50' AGL). This corresponds to 48 files per receive site, 136 receive sites and 6,528 files total for one round of testing. Since two rounds of testing were conducted for the two different transmit antennas, a total of 13,056 data files were captured. An example of two measurements taken at site number 05 with a 30' antenna height are shown in Figure 5.2.

In addition to the individual power contributions, a total power measurement was made at each test site and antenna height using a power measurement personality for the spectrum analyzer. The personality allowed the analyzer to measure the total power in a specified bandwidth. One measurement was made at each antenna height and the data was stored in a spreadsheet. Information was also stored in the spreadsheet on the test site distance and bearing to Tucson House based on a GPS device.

Installation of the return path and hub systems took approximately 4 weeks to complete. Upon completion of the system setup, the first round of testing took approximately two weeks. The return path transmit antennas were then changed and signal levels readjusted over a 3 week time period. The second round of data collection took approximately 3 weeks.

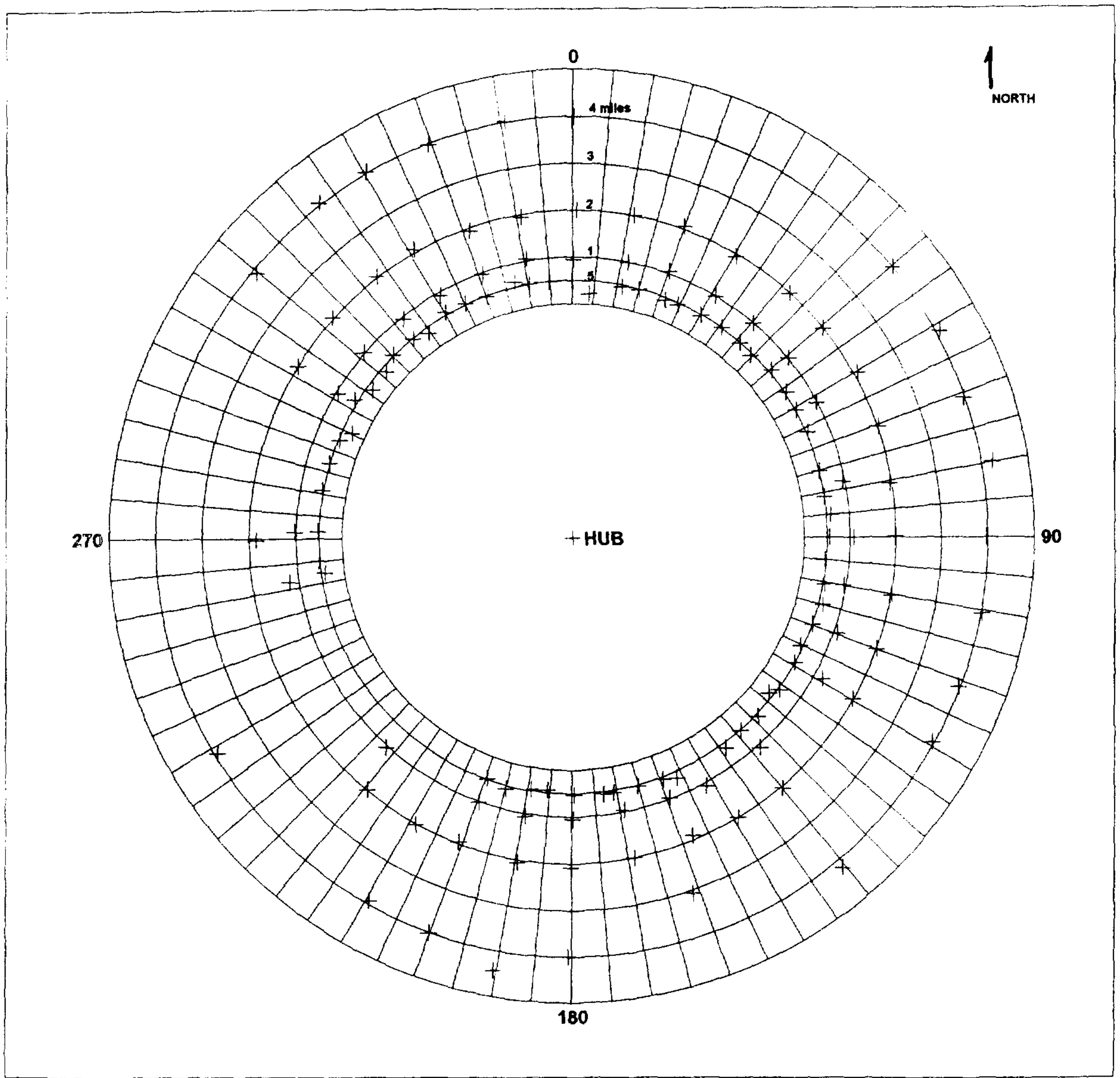
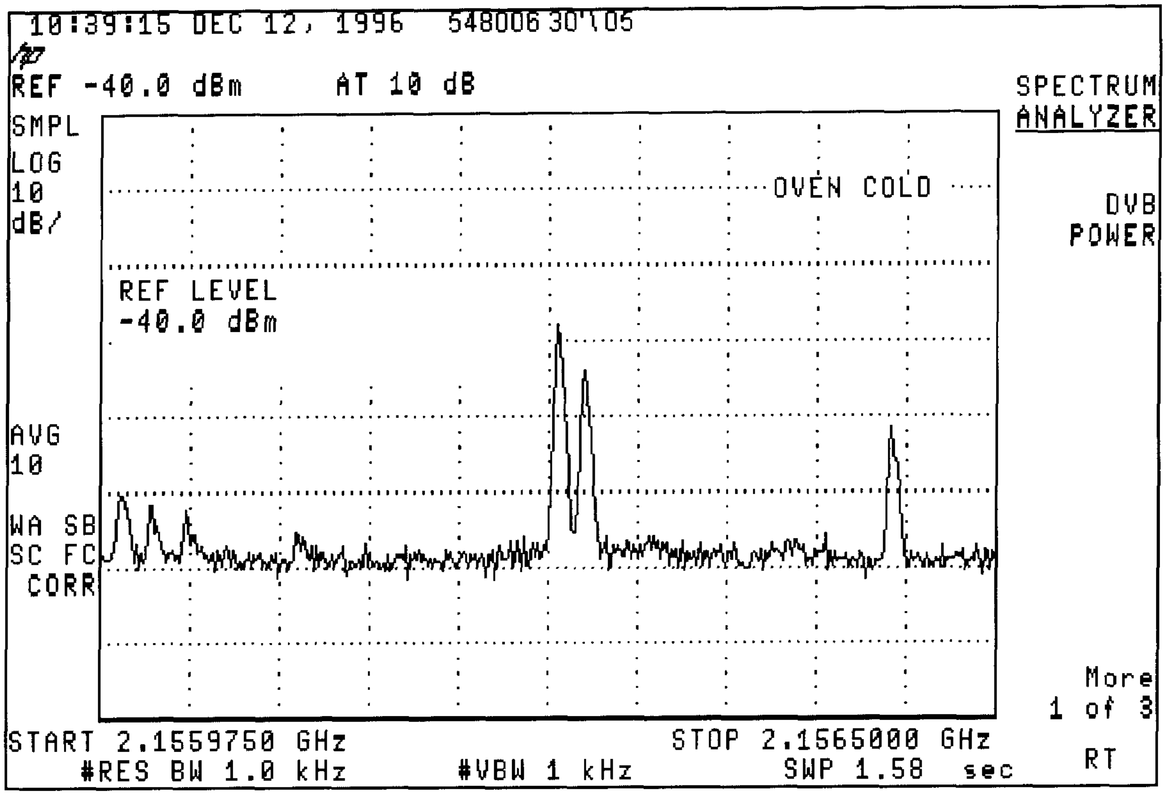


FIGURE 5.1 - LOCATION OF TEST SITES AROUND CELL.



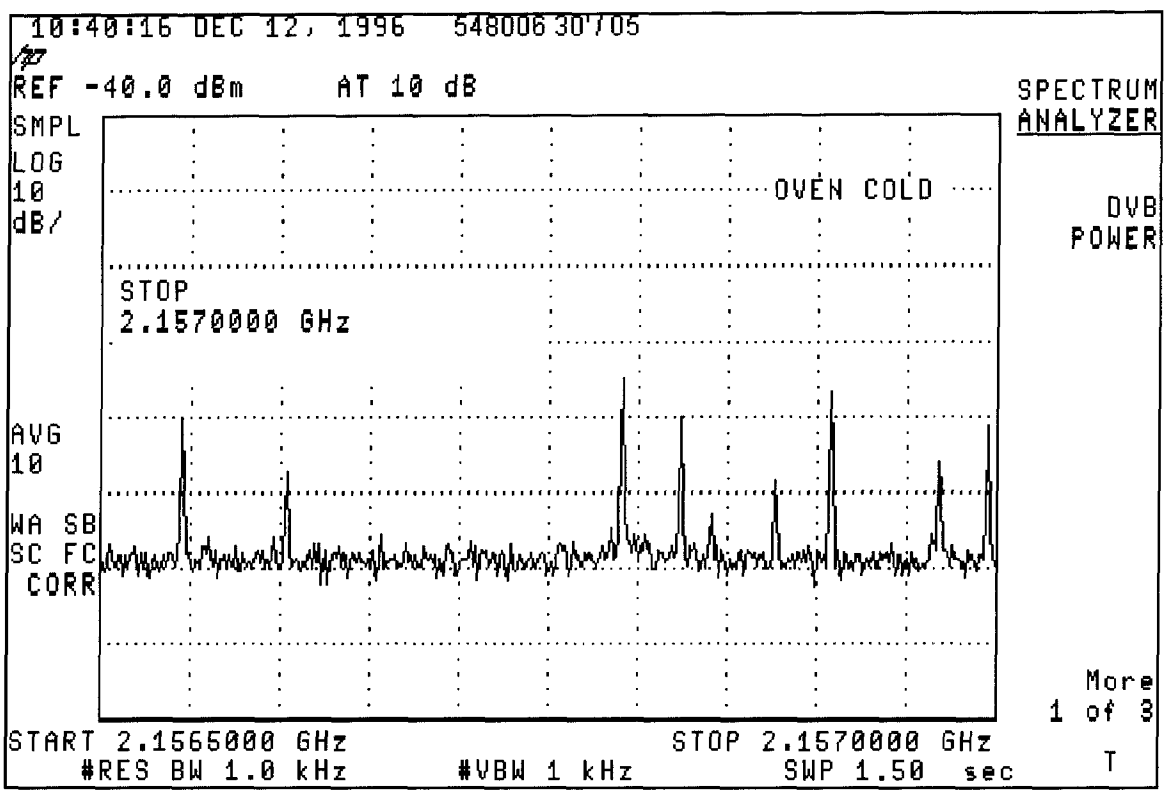


FIGURE 5.2 - EXAMPLE OF DATA COLLECTED AT A SINGLE TEST SITE

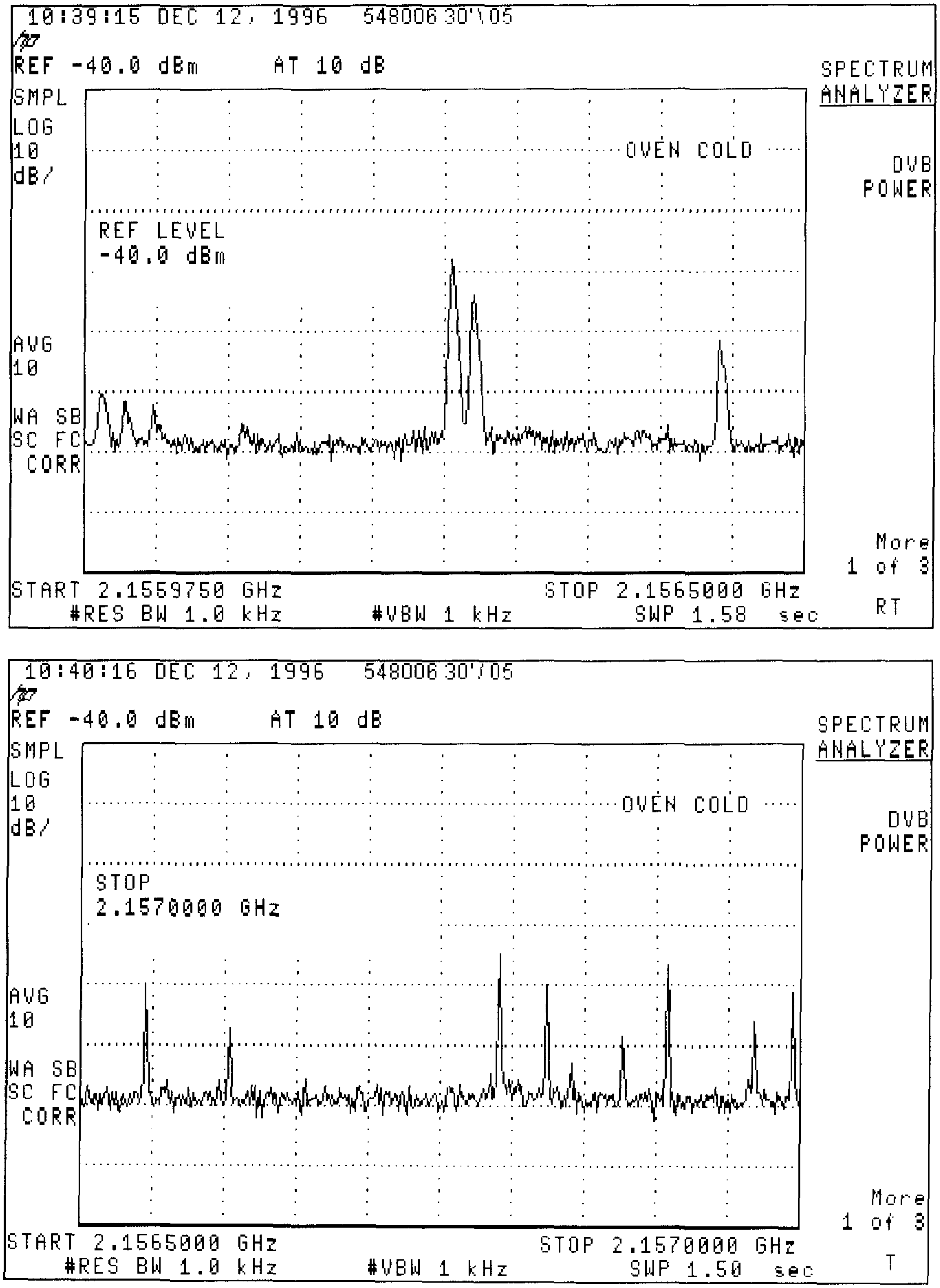


FIGURE 5.2 - EXAMPLE OF DATA COLLECTED AT A SINGLE TEST SITE

5
Results

In order to evaluate the ability of the methodology to predict signal levels accurately, it is necessary to compare the actual data taken for the total power measurements at each test site with the predicted levels. The most convenient method for presenting this information is on a signal strength map. However, there currently does not exist a single software package with the ability to accumulate signal strength data from multiple transmit sites as is needed for this analysis. Therefore, a series of software packages had to be utilized to generate the theoretical data from the methodology and to generate the signal strength maps.

Measured vs Predicted, No Terrain

Attached as Figures 6.1 through 6.3 and 6.7 are a series of signal strength maps showing comparisons of the total accumulated power from the measured data to the predicted data with the effects of terrain removed from the prediction model. The measured data is represented by a star symbol on the map and is shown at its exact location relative to the cell. The color of the star is representative of the measured total power level in the 4 MHz channel at that site and the magnitude is defined by the map legend. The predicted accumulated power levels are shown as composite contours on the map and utilize the same colored signal strength legend as does the measured data. Therefore, if a received signal level from the measured and the predicted data were the same, the color of the star would be exactly the same as the region of the map which contains the star.

As can be seen from these maps, the measured received signal levels are always significantly less than the predicted received signal levels when the effects of terrain are ignored. The model would be overly conservative if the effects of terrain were not considered.

Measured vs Predicted, Terrain

Attached as Figures 6.4 through 6.9 are a series of signal strength maps showing comparisons of the total accumulated power from the measured data to the predicted data with the effects of terrain included in the prediction model. A propagation model utilizing the free space + RMD method of analysis was utilized. When terrain is included in the prediction model, the predicted received signal level is significantly reduced and comes closer to matching the measured data. However, in all but one of the 408 tests conducted, the levels predicted by the accumulation methodology remain stronger than the measured data. There is one test site when measured at the 30 ' level where the measured data is actual stronger than the predicted data. This site is located on the edge of a steep valley in the mountains to the southwest of Tucson. This becomes more apparent by examining the 40' and 50' maps at this same site which show the valley beginning to grow as the antenna height is increased. At the 30' level, the accuracy of the 3 second terrain database predicts the site to be more obstructed than the actual data. However, once the receive antenna is raised to 40', the predicted and measured data fall in line with one another. This certainly represents an excellent margin of error for the model and results in a very conservative estimation of the actual received signal level of a return path system.

Another factor not considered in the model which adds additional conservatism is excess path loss due to obstructions caused by foliage and buildings. Since the return path transmitters are at roof top level or slightly above, structures with heights just slightly above roof line will significantly affect the signal level received outside of the cell. Tucson did not contain a heavy amount of foliage nor was there an extremely large downtown area.

Transmit Antenna Pattern

Both the predicted and measured results of the test show significant variations in accumulated power levels based on the antenna pattern of the return path transmission system. Both the shape of the received signal areas and the magnitude of the levels in these areas changed with the different antenna patterns. Therefore, it is essential the antenna patterns to be utilized in the system design be included in the prediction model.

RECEIVED POWER LEVELS = ACTUAL TRANSMITTERS

Received Power Data (30 foot)

☆	-38 to 32	(11)
☆	-44 to -38	(11)
☆	-50 to -44	(20)
☆	-56 to -50	(45)
★	-62 to -56	(33)
★	-73 to -62	(14)

Tx Pwr = Actual - Terrain

■	-26 to 0	(1983)
▒	-32 to -26	(2239)
	-38 to -32	(253)
■	all others	(14)

FIGURE 6.2 - 12 DBI TRANSMIT ANTENNA, MEASURED VS PREDICTED ACCUMULATED POWER, 40' RECEIVE ANTENNA HEIGHT, NO TERRAIN EFFECTS

RECEIVED POWER LEVELS = ACTUAL TRANSMITTERS

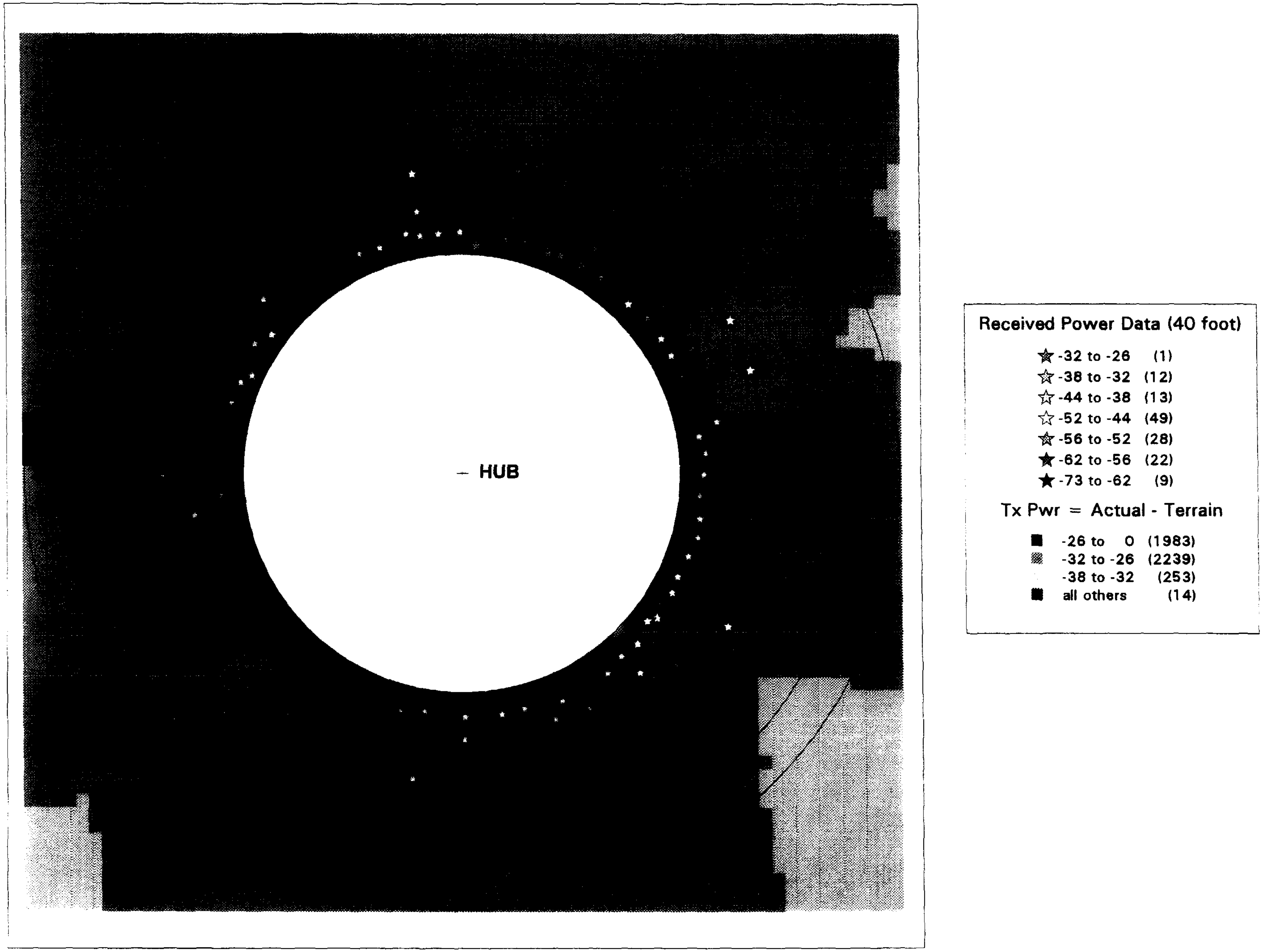
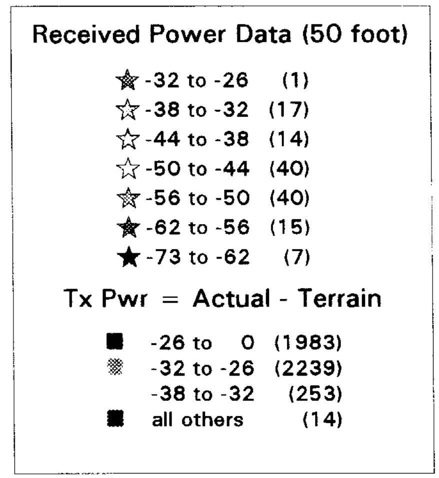


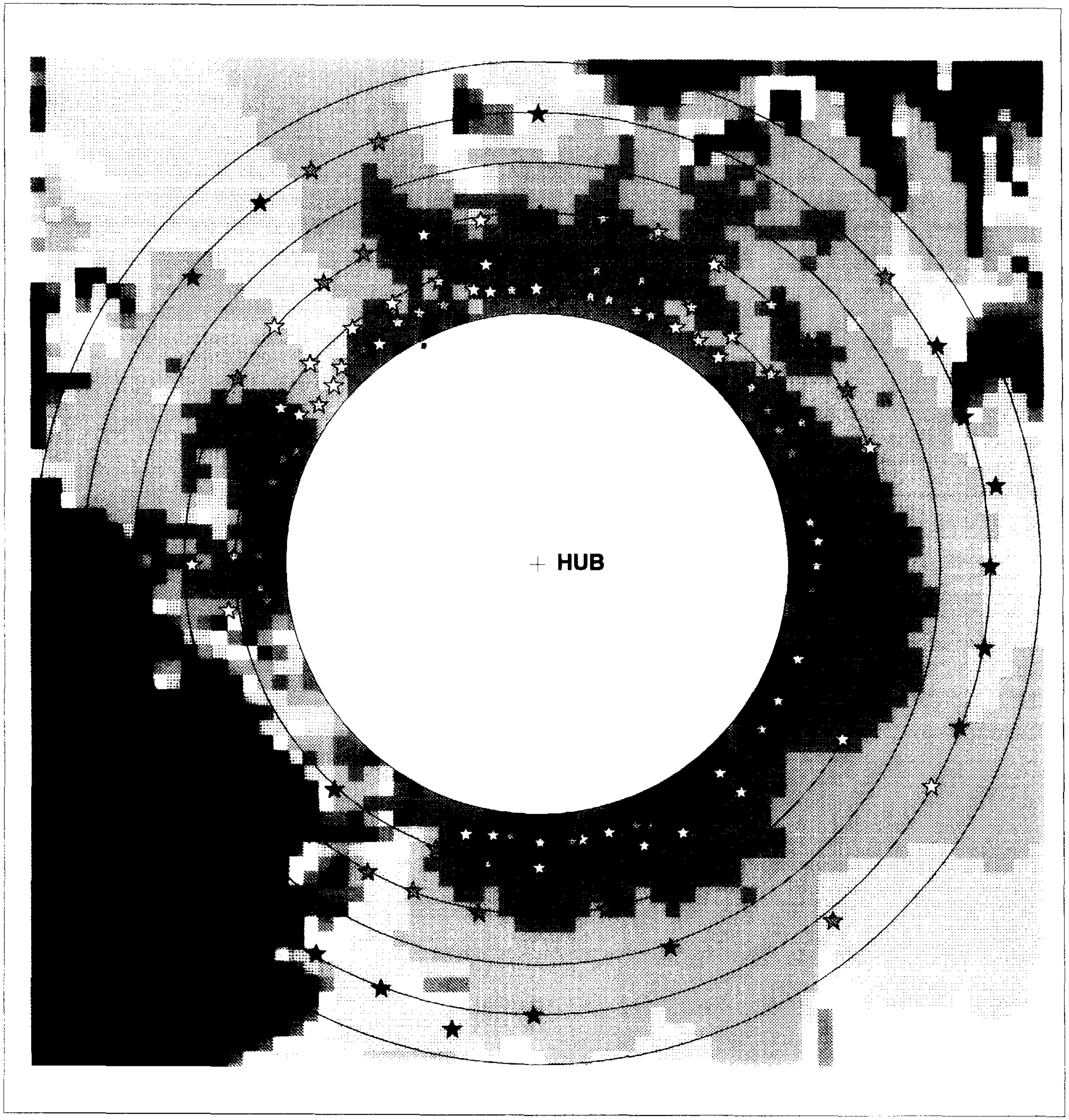
FIGURE 6.3 - 12 DBI TRANSMIT ANTENNA, MEASURED VS PREDICTED ACCUMULATED POWER, 50' RECEIVE ANTENNA HEIGHT, NO TERRAIN EFFECTS

RECEIVED POWER LEVELS = ACTUAL TRANSMITTERS



<u>FIGURE 6.4 - 12 DBI TRANSMIT ANTENNA, MEASURED VS PREDICTED ACCUMULATED POWER, 30' RECEIVE ANTENNA HEIGHT, TERRAIN INCLUDED</u>

RECEIVED POWER LEVELS = ACTUAL TRANSMITTERS + TERRAIN



Received Power Data (30 foot)

★ -26 to 0	(1)
☆ -38 to -32	(11)
☆ -44 to -38	(27)
☆ -50 to -44	(38)
☆ -56 to -50	(36)
★ -62 to -56	(18)
★ -68 to -62	(6)

Tx Pwr = Actual + Terrain

-26 to 0	(821)
-32 to -26	(778)
-38 to -32	(1171)
-44 to -38	(706)
-50 to -44	(210)
-56 to -50	(68)
-62 to -56	(58)
-68 to -62	(98)
all others	(579)